Proposal For a Teaching Demonstration Workbench Thermoelectric Effect

Oswaldo Hideo Ando Junior [*1], Cleber Lourenço Izidoro[2], João Mota Neto[3], Mario Orlando Oliveira[4], Lirio Schaeffer[5]

[*1,2,3]Department of Electrical Engineering, Faculdade SATC

Criciúma, Santa Catarina, Brasil

[4]Energy Study Center to Development (CEED), National University of Misiones –UNaM,

Oberá, Misiones, Argentina.

[5]Mechanical Transformation Laboratory, University Federal of Rio Grande do Sul – UFRGS

Porto Alegre, Rio Grande do Sul, Brasil

[*1]oswaldo.junior@satc.edu.br; [2]cleber.izidoro@satc.edu.br; [3]joao.neto@satc.edu.br; [4]*oliveira@fio.unam.edu.ar;* [5]schaefer@ufrgs.br

Abstract

This article presents a proposal for development of a didactic strand for demonstration of the Seebeck, Peltier effects and for testing to obtain performance curves of the modules and thermoelectric materials having the property when subjected to a potential difference to generate a temperature gradient between its faces (Peltier) and subjected to a temperature gradient, generating a potential difference between their terminals (Seebeck). The workbench proposal is composed of a thermal system that has the functions of heating and cooling followed by a data acquisition system (temperature, voltage, current and power output) which will allow the visualization of measured quantities in the form of graphs and a software developed in Delphi® that enables monitoring of the effects during the experiments and obtains the performance curves of thermoelectric materials. A prototype of the workbench didactic proposal and the validation results have been discussed in the conclusion.

Keywords

Didatic Workbench, Thermoelectric, Peltier Effect, Seebeck Effect, Learning.

Introduction

One of the major paradigms of education is to attempt to change the outdated form of the learning process. As it can be seen in most educational institutions that a lesson always comes down to the traditional method, students listening and speaking teacher, very few times using other tools to verify the contents assimilated. Through practical examples, teaching resources technological interaction and direct contact with the student have been widely used (Moram,J.M., 2004).

One way to check the level of learning in the classroom is through the use of teaching resources technology that enables academic development practices or experiments related to the content covered in class, such as didactic workbenchs.

The object of this paper are thermoelectric materials subjected to a temperature difference to generate electricity. As it can be observed that there are several quantities analyzed to confirm these effects, such as temperature, voltage and current generated (Nascimento A., Lubanco, J. C.,Moreira T. A., 2012).

To visually analyze all this greatness, we need to measure this information, in this case where there will be a didactic workbench for the academic and tests will be performed by varying temperature to prove the power generation, the effect of thermoelectricity.

Therefore, this paper presents the development of a didactic workbench with low cost to enable the student to prove the concepts discussed in the classroom through practical experiments.

It is noteworthy that the thermoelectric materials can be applied in various branches of engineering, such as, renewable energy, physics study, and other applications. Therefore, using the workbench proposed, the academics can verify that from temperature variations there will also be variations in current and voltage generated from thermoelectric material.

Thermoelectric Effects

The thermoelectricity is the property that some materials hold to generate electricity based on the temperature difference applied to its terminals and vice versa. Two phenomena can be studied to better

understand the functioning of these materials, the Seebeck effect and the Peltier effect.

Seebeck Effect

The thermoelectric effect was discovered in 1821 by Thomas Johann Seebeck (physicist born in 1877 and died in 1831), stating that when two distinct conductive materials applied to a temperature difference can generate a potential difference (voltage) between their terminals, as shown in Figure 1A. If there is a load on the output of this material, an electric current is generated, as shown in Figure 1B.

This phenomenon is called the Seebeck coefficient (α), which can be observed in a well-known device, the thermocouple element used for temperature measurement:

$$\alpha = \frac{\Delta V}{\Delta T} \qquad (1)$$

α $\Rightarrow$ Seebeck Coeficient

ΔV $\Rightarrow$ Voltage Range

ΔT $\Rightarrow$ Temperature Range

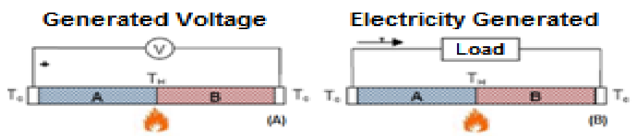

FIG. 1 SEEBECK EFFECT

(Campos, D.N., Oliveira, T.C., 2011)

Later, another physicist, Jean Charles Athanase Peltier (1785- 1845) described a metal junction that can produce cold or heat, that is the so-called "Peltier effect"providing that two distinct materials when subjected to a potential difference does occur producing temperature gradient, namely the inverse process to the Seebeck effect.

Depending on the direction of current heat can be released or absorbed, which can be seen in Figures 2A and 2B.

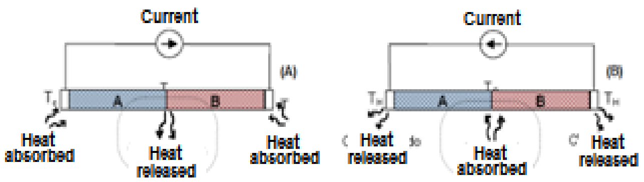

FIG. 2 PELTIER EFFECT

(Campos, D.N., Oliveira, T.C., 2011)

The quantification of this effect is the Peltier coefficient (π):

$$\pi = \alpha . T \qquad (2)$$

Thermoelectric Materials

Thermoelectric materials are semiconductors formed when applied to temperature differences that can generate energy in the form of electrical voltage.

Thermoelectric modules, typically formed by semiconductor materials, have its structure formed to increase the current density and hence the output power. Are manufactured from materials such as tellurium, antimony, germanium and silver, with high doping to create semiconductor materials (Campos, D.N., Oliveira, T.C., 2011).

These in turn are welded in a sandwich of two ceramic plates, to ensure heat transfer and sufficient mechanical strength. Figure 3 shows how the formation of the tablet, with PN junctions connected in series.

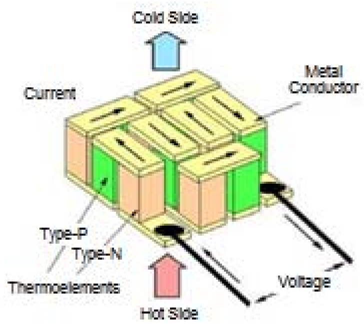

FIG. 3 FORMATION OF THE THERMOELECTRIC MODULE
(Campos, D.N., Oliveira, T.C., 2011)

By the application of a temperature greater on one side, there is a current flow constant over the semiconductor material, and therefore a voltage is formed by the association of several elements.

All commercial thermoelectric modules based on the principle mentioned above, are manufactured for different values of temperature, size and power. Figure 4 shows a commercial tablet.

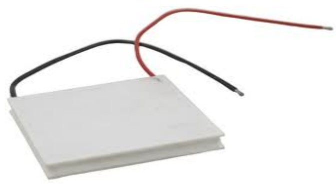

FIG. 4 COMERCIAL THERMOELECTRIC MODULE

(Souza, D.H., 2007)

Among the advantages of thermoelectric materials, the high reliability, low maintenance, application

versatility, size, lightness, low noise generation, and highly secure are listed (Farias, S.R.A., 2009)

With the development of thermoelectric materials, it can be applied in various areas meeting operating conditions. For example, it can be used for power generation in industries where heat loss is present (thermoelectric power plants, foundries), or even in the exhaust of a car. In these two cases, there may be a considerable increase in overall system efficiency.

In other cases, its use covers cooling of foodstuffs, electronics and air conditioning systems (but it should be considered that the cooling efficiency is still low compared to existing devices such as compressors) (Riffat, S.B., MA, X., 2002).

Brief State of the Art

We highlight below some work related to the measurement of thermoelectric phenomena.

Study Platform for Intelligent Control Applications and Embedded Systems

The platform studied in question proposes the remote programming of a microcontroller to perform the temperature control, via a thermoelectric module to make it possible to remotely check the heating of an aluminum disk and cooling module through a blower, and it will be possible to apply some theories as PID or fuzzy control. Figure 5 shows the schematic of the process (Araújo, T.G.P., Filho, C.A., 2005).

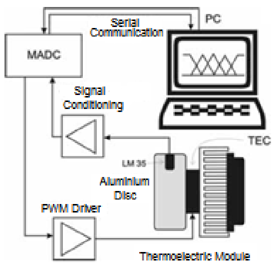

FIG. 5 PLATFORM FOR INTELLIGENT CONTROL APPLICATIONS

(Araújo, T.G.P., Filho, C.A., 2005)

Didactical Workbench for the Study of Thermoelectric Generators

The counter of didactic for the study thermoelectric generators has the function of checking the power output signal and monitoring the temperature gradient. The system comprises a thermoelectric module, heat sinks and resistors calibrated load, and by measuring signals through analogue instruments (multimeters), a power source and a thermal camera can make the analysis of thermoelectric effects. Figure 6 shows the workbench and equipment used (Bobean C., Pavel, V., 2012).

FIG. 6 DIDACTICAL WORKBENCH FOR THE STUDY OF THERMOELECTRIC GENERATORS

(Bobean C., Pavel, V., 2012).

Mini-Laboratory Educational for Experimental Studies to the Concept of Renewable Energy

As it can be seen in Figure 7 that this workbench has the function to study the various phenomena of renewable energy, such as thermoelectric, photovoltaic, solar, and so on. As this workbench encompasses many different technologies, there is also the possibility to study thermoelectric materials for waste energy, even there is the possibility to combine other renewable energy technologies for analysis (Yildiz, F., Coogler, K.L., 2012).

FIG. 7 MINI-LABORATORY EDUCATIONAL FOR EXPERIMENTAL STUDIES TO THE CONCEPT OF RENEWABLE ENERGY

(Yildiz, F., Coogler, K.L., 2012).

Propose Didatic Workbench

The proposed workbench is that it is mobile, easy installation and configuration, and has concentrated all measurements in one device, ie, a complete system (hardware and software).

With the proposed workbench, the following thermoelectric effects can be monitored, among which the Seebeck effect, Peltier and Thomson are highlighted. While in the area of testing real performance thermoelectric modules will allow the lifting of the curve for various applications for cooling

and power generation, since the proposed system is cappable to make the acquisition and storage of test data for future comparative analyzes.

Among the possible configurations and experiments to be carried out with the counter proposal, is the schematic layout shown in Figure 8, in which the application is to use thermoelectric modules for power generation and the existence of a power source can be observed obtained from waste energy, for example, and a cold source system that may be a finned heat transfer or heat pipe, and finally a thermoelectric module that loads can feed as resistors or battery charging systems and LED lighting.

The experiment consists of collect the electrical signals of the generator (voltage, current and power) as a function of temperature variations, and through the system data acquisition workbench (dotted lines) a measurement can be taken to demonstrate the effectiveness of this application.

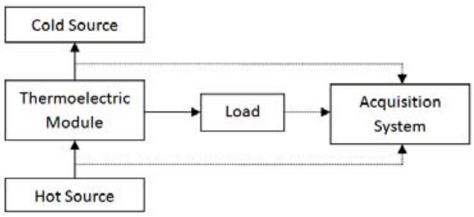

FIG. 8 INSTALLATION METHOD OF WORKBENCH

To study the thermoelectric effect, some quantities must be considered, for example, the temperature gradient, the voltage generated, current generated, and thus the generated power.

The proposed acquisition system is shown in Figure 9, which basically consists of the following parts:

- Electronic System Microprocessor for temperature acquisition;
- Electronic microprocessor system for the acquisition of electrical quantities (voltage, current and power);
- Software acquisition.

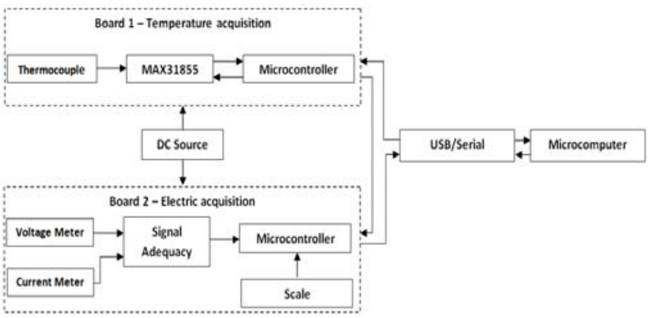

FIG. 9 SYSTEM OVERVIEW

Temperature Acquisition

According to Figure 9, the plate 01, possesses certain temperature for acquisition of thermocouples, and the design idea is up to eight temperature measurements that are divided into four channels, namely a signal for temperature and one for high temperature.

These temperature sensors are operated on the Seebeck effect to generate, when subjected to certain delta temperature, a small amount of voltage (usually at the home of mV), a value proportional to the temperature (Moreira,L., 2002).

Operation of Temperature Board

For this project, a type K thermocouple will be employed, which can handle temperatures from -270 to 1200°C. As the thermocouple generates very small voltages, in mili volts, and also does not have a linear curve, a signal conditioner is necessary, which linearizes and amplifies the signal (Pirometrica, 2013).

In the market, there are some types of conditioners, amplifiers, for this project, the MAX31855K of Maxim is appropriate, which captures the signal from the thermocouple and through synchronous serial communication microcontroller sends the temperature signals and failure signals, as shown in Table 1 (Maxim, 2012).

TABLE 1 SENT BIT MAP

	14-BIT THERMOCOUPLE TEMPERATURE DATA				RES	FAULT BIT	12-BIT INTERNAL TEMPERATURE DATA				RES	SCV BIT	SCG BIT	OC BIT
BIT	D31	D30	...	D18	D17	D16	D15	D14	...	D4	D3	D2	D1	D0
VALUE	Sign	MSB 2^{10} (1024°C)	...	LSB 2^{-2} (0.25°C)	Reserved	1 = Fault	Sign	MSB 2^{6} (64°C)	...	LSB 2^{-4} (0.0625°C)	Reserved	1 = Short to V_{CC}	1 = Short to GND	1 = Open Circuit

Electric Aquisition

To acquire the electrical signals needed to raise the voltage and current of differential form, i.e, the reference signal is different plate reference signal measurement. Based on the above, an electronic circuit with operational amplifiers in setting Subtractor should be designed in order to adjust the gain value pair so that the microcontroller can start reading.

For measuring, the electric voltage has been made adjustment on gain amplifier for the same voltage input placed at the output, besides the possibility of scaling, making possible to measure voltages up to 15 V.

As for the electric current, the same circuit can be used, only using a charging resistor (shunt) and by adjusting the gain at the output of the circuit the same value of input current can be measured, for example, if the

current is 100 mA, the output has a voltage of 100 mV. In this case, currents up to 5 A can be measured generated from the thermoelectric modules.

Acquisition System

To total data acquired visually, a software developed in Delphi© visual environment will capture information from microcontroller through the serial port, these acquired signals are shown graphically, with the possibility of the data being saved for future analysis.

Main Display

Figure 10 shows the main screen of the software,including four different graphs, the first of which shows the temperature value, in this case the temperature of the joint red hot in blue and black CJ the resultant of these two values (gradient) .

The second graph shows the voltage generated in Volts, the third current in Amperes and the latter the result of these two values, the Electric Power generated in the module in Watts.

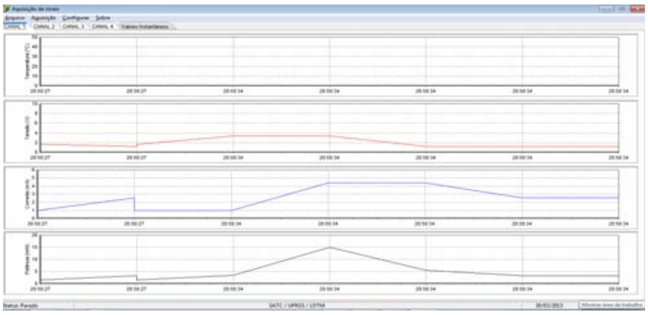

FIG. 10 MAIN DISPLAY OVERVIEW

Software Menus

Through the program menu settings may be made as: save, save as, communication settings and acquisition. Figure 11 shows the configuration screen graphics, which has the function to adjust the full scale of the graphics and qualification or otherwise of each channel individually, because in some cases there will be variations in the magnitude values and measurements that will be made.

FIG. 11 CONFIGURATION MENU

Flowchart of Operation

Communication between devices always starts with the computer sending the information to the acquisition boards.

Always one sequence will be performed as described in Figure 12, and the first plate receives an information from the computer case if the received information is an application temperature, the card sends a feedback to the microcomputer which makes the analysis of information and aggregation via graphs.

If information fails to receive temperature value, this is passed on to the next plate, which makes analysis of receipt if a value of voltage or current will be sent back to the computer.

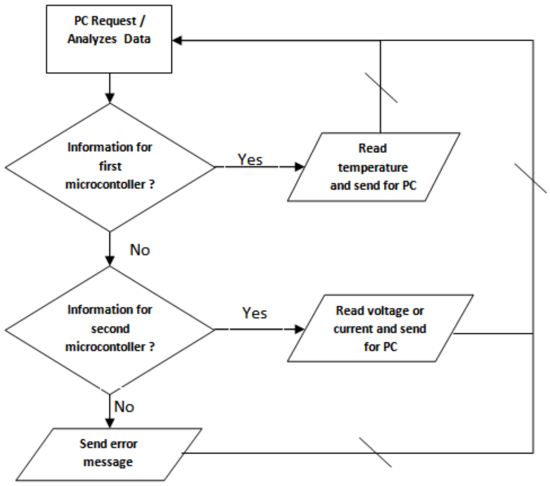

FIG. 12 MAIN DISPLAY OVERVIEW

Expected Results

The tool will become insignificance for experimental analysis of processes related to thermoelectricity because all monitoring will be only concentrated ona system of acquisition, in addition to mobile, easy to install and use. Another important factor is that the storage of information brings great possibilities for further comparison of tests and analysis for various values of temperature gradient.

One way is to use the workbench to obtain efficiency curves of thermoelectric modules. Each type of module can respond differently, according to the temperature or type of material with which it was manufactured. Through performance tests then comparisons can be made for each type of application and instantly the performance is gained.

With its use, it will be possible to create various

thermal and electrical arrangements in order to obtain experimentally the topology with better efficiency for a particular application, either for cooling or generation of electricity.

Conclusions

This article presents a proposal for development of a didactic workbench for demonstration purposes by means of thermoelectric thermoelectric modules.

Through this workbench, practical experiments will be done involving thermoelectric modules, thermal and electrical (connected in series or parallel) arrangements, variation of loads (resistors, motors or LEDs), and through the acquisition system graphs tracking and aggregation of data has been generated, and through experiments the subjects covered in the classroom have been domenstrated as well.

REFERENCES

Araújo, Tomás V. G. P. ; FILHO, Carlos A. S.; et al. "Plataforma de estudo para aplicações de controle inteligente e sistemas embarcados". VII SBAI/ II IEEE LARS. São Luís, setembro de 2005.

Bobean, Crina; PAVEL, Valentina; et al. "Didactical workbench for the study of thermoelectric generators". Buletinul AGIR n. 3/2012.

Campos, D. N.; Oliveira, T. C.. "Controlador de Temperatura Microprocessado Utilizando Célula Peltier". 84 f. Monografia(Engenharia Elétrica). Universidade Gama Filho. Rio de Janeiro, 2011.

Farias, Sandro Ricardo Alves. "Protótipo de um microgerador termoelétrico de estado sólido: cogeração a gás". 2009. 98 f. Dissertação (Mestrado) – Universidade Federal do Rio Grande do Norte. Natal, 2009.Maxim Semiconductor, Datasheet. "MAX31855 Cold-Junction Compensated Thermocouple-to-Digital Converter". Maxim Semiconductor, 2012.

MORAN, J.M. Os novos espaços de atuação do professor com as tecnologias. IN:Anais do 12º Endipe – Encontro Nacional de Didática e Prática de Ensino, in ROMANOWSKI, Joana Paulin et al (Orgs). "Conhecimento local e conhecimento universal: Diversidade, mídias e tecnologias na educação". vol 2, Curitiba, Champagnat, 2004, páginas 245-253.

Moreira, Lúcia. "Medição de temperatura usando-se termopar. Revista Cerâmica Industrial". Volume 7, p. 5,6. Setembro/Outubro, 2002

Nascimento, A. et al. "Fontes Alternativas de Energia Elétrica: Potencial Brasileiro, Economia e Futuro. Bolsista de valor". Revista de divulgação de Projeto Universidade Petrobras e IF Fluminense. v. 2, n. 1, p.23-36, 2012.

Pirométrica. "Termpopares". Disponível em http://www.pirometrica.com.br/paginas/produtos/termopar/termopares.html. Acesso em 05/03/2013.

Riffat, S.B.; Ma, Xiaoli. "Thermoelectrics: a review of present and potential applications". School of the Built Environment, The University of Nottingham. Dez. 2002.

Souza D. H.. "Otimização do Uso de Refrigeradores Termoelétricos em Processos de Refrigeração". 59f. Monografia(Engenharia Mecânica) Universidade de Brasília, Brasília, 2007.

YILDIZ, Faruk; COOGLER, Keith L. "Design and development of a multiple Concept educational renewable energy mobile mini-lab for experimental studies. International journal of engineering research and innovation". V4, N2, fall/winter 2012.

Oswaldo Hideo Ando Junior majored in Electrical Engineering and specialization in Business Management from the Lutheran University of Brazil - ULBRA with a Masters in Electrical Engineering at the Federal University of Rio Grande do Sul – UFRGS. Currently, he is lecturer of Electrical Engineering, Faculty SATC. Reviewer ad hoc FAPESC and PMAPS. His work interests are mainly in the areas: Energy Conversion, Power Quality and Power Systems.

Cleber Lourenço Izidoro majored in Technology Industrial 'Automation from the University of Southern Catarinense (2006) and specialization in Industrial Automation and Technology Center for Automation and Informatics (2007). Professor of Faculty SATC. He has experience in Robotics, Mechatronics and Automation.

João Mota Neto graduated in Industrial Automation Technology at the University of Southern Santa Catarina and received master's degree in mechanical engineering-UFRGS. Currently, he is lecturerof electrical

engineering and industrial automation technology in the Faculty SATC Developing research in the areas of energy efficiency, instrumentation and automation.

Mario Orlando Oliveira (M'09) was born in Capiovi, Misiones, Argentina, on May 13, 1979. He received the Eletromechanical Engineering degree from the National University of Misiones (UNaM), Argentina, in 2005 and M.Eng. degree from the Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Brazil, in 2009. Currently, he is researcher of the Energy Study Center to Development (CEED) and auxiliary professor of the UNaM. His research interests include electrical machines protection and modeling, faults detection and location.

Lirio Schaeffer Ph.D. in Mechanical Forming Rheinisch Westfalischen Technischen Hochschule/Aachen, R.W.T.H.A., Germany. Professional performance: Coordination of Improvement of Higher Education Personnel, CAPES, Brazil. 2003 -Present – Relationship: Employee Department of Metallurgy, UFRGS, Brazil.1974 - Present - Public Servants, Functional Placement: Teacher, Exclusive Dedication.